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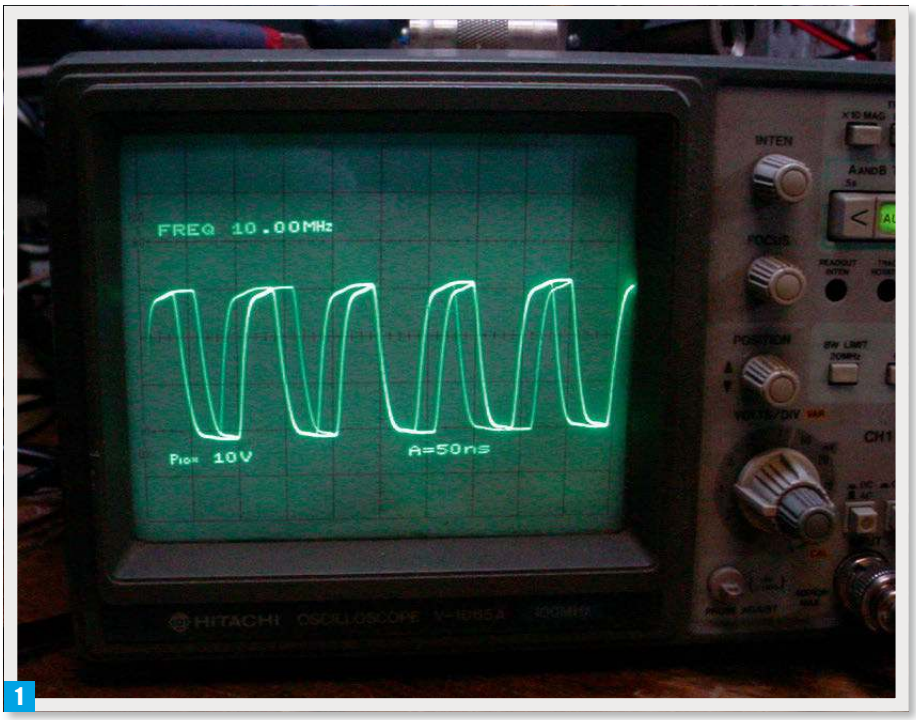
A GPS-disciplined 10MHz Frequency Standard

Eric Edwards GW8LJJ describes a highly-accurate 10MHz frequency standard, handy for a number of purposes around the shack, for example when setting up for Es'Hail 2 as described

A known accurate frequency source is a very useful addition to the shack because it can be used to calibrate frequency counters (frequency meters) and also used as a reference for the counter and for transceivers that have a reference input. The frequency chosen is 10MHz because that seems to be a popular frequency to use for reference.



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How Accurate is it?

The accuracy of the project described is governed by the GPS signals that are being sent out from many satellites. There are two settings, one with the GPS antenna connected and another that relies on the internal TCXO (temperature compensated crystal oscillator). The frequency selected is stored in a 'flash' memory so no back-up battery is required.

The GPS device

The device used is the GPS receiver and the type used is the Ublox NEO-7N, which suits the purpose very well for this application. My first attempt was using the NEO-7M, a larger module, and it worked as long as a battery backup was used to enable it to be powered down and back up some time later. There is a small battery fitted on the module but a bigger one would be better if I was to use that device. I chose the -7N type because it has an SMA GPS antenna socket fitted, a pps (GPS output) pin and a flash memory. The -7M has none of these easy access parts and because the memory of the -7N is a flash type it doesn't need a back-up battery.

The Concept

There are several designs using the Ublox GPS modules where the output frequency is taken directly from the module. This is acceptable for lower frequencies but above 2MHz there is phase distortion. The photo, **Fig. 1**, shows this distortion when the 10MHz is taken direct from the GPS module. I have chosen to use 2MHz as the base frequency and multiply to 10MHz by using a frequency multiplier integrated circuit (ICS501) set to multiply by times five. This produces a stable 10MHz signal and I have used an Op-Amp to adjust the output level and change the impedance to 50Ω. This is done with a high frequency Op-Amp (LT1221) and then it goes into a simple three-pole lowpass filter to produce a clean 10MHz sinewave, **Fig. 2**, with no appreciable harmonics, **Fig. 3**.

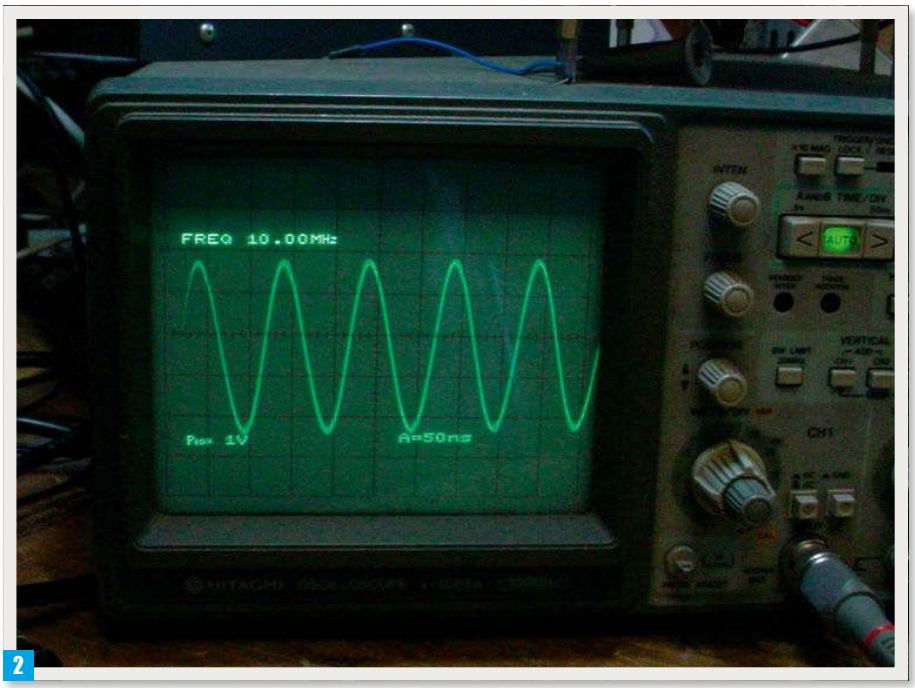
Placing the Required Frequency in the GPS Module

Loading the required frequency to the GPS module requires software but once the frequency is loaded into the module's memory with the UART (Universal Asynchronous Receiver/Transmitter), this interface is no longer required in order to use with the frequency standard. Those of you that want to load the GPS module can download the software at the U-blox u-center. It will be pre-loaded if obtained from me.

The Circuit Diagram

The circuit is shown at **Fig. 4**. The main component is the GPS module and the type used is a Ublox NEO-7N for the reasons described above: flash memory, no back-up memory battery needed, the GPS antenna (SMA) connector is pre-fitted and there is a dedicated pin for the PPS (GPS output signal). None of these are on the NEO-7M version.

The PPS signal from the GPS module has been programmed to provide a 2MHz square-wave with a duty cycle of 50% at



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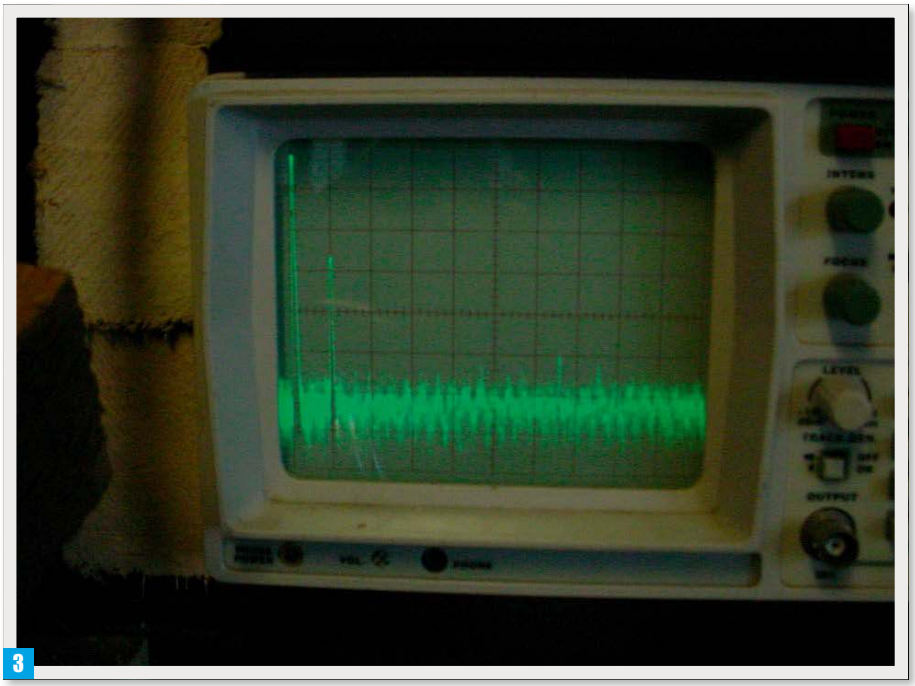

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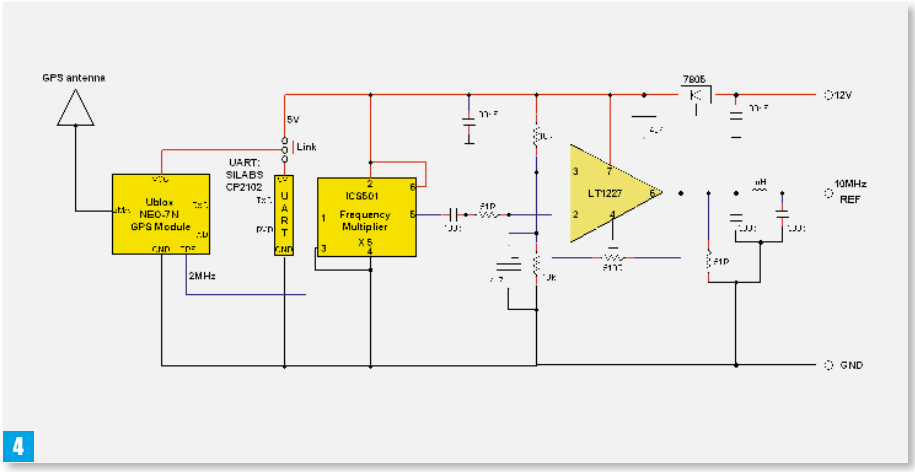

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Fig. 1: 10MHz phase distortion on signal taken direct from GPS module.
Fig. 2: Cleaned up 10MHz signal.
Fig. 3: Spectrum of cleaned-up 10MHz signal.
Fig. 4: Circuit diagram.

4V pk-pk (peak-to-peak). It is connected to a frequency multiplier (ICS501). This integrated circuit is a PPL (Phase Locked Loop) and is an SOP8 type that I have placed onto an adaptor to convert to DIL (Dual In Line) so it can be used with the standard through-hole PCB footprint.
The output with 2MHz applied provides a 10MHz sinewave at 5V pk-pk waveform. Because a filter is required to remove, or greatly attenuate any harmonics, the signal output from the multiplier needs to be converted to low impedance and the gain adjusted. This is carried out by the next stage, which is an Op-Amp (LT1227), and although set for a gain of ten (510Ω/51Ω) it can be set for any other gain by changing the resistor combination. This is a high frequency Op-Amp and used for video applications. The output from this amplifier is placed at 50Ω for the sending impedance to the three-pole lowpass filter to provide a clean 5V pk-pk sinewave with no appreciable harmonics.

PCB Layout

The PCB layout is shown in **Fig. 5**. The NEO-7N GPS module is shown on the left of the PCB and next to it is a six-way DIL socket that is used for placing a UART for programming the NEO module (once programmed, the UART can be removed). Below the NEO module is a three-way DIL socket and a link is supplied that selects either 5V for the NEO module from the external 12V power supply for normal use or the 5V supplied from the UART when programming. A UART can be obtained from me if you want one but if using your own, the type has to be a SILAB CP2102 type because of the pin labelling for interfacing with the NEO module. Others can be used but their pin positioning may be different.
The IC (ICS501) is the frequency multiplier to bring the 2MHz square-wave output, **Fig. 6**, from the GPS module to an almost pure 10MHz sinewave, **Fig. 7**. This output is taken to an Op-Amp (LT1227) chosen because it is a high frequency type usually used in video circuits. The gain has been set for times ten and the output impedance to 50Ω. The output at pin 6 is taken to a simple three-pole lowpass filter to provide a clean 1MHz sinewave.

Is There a Kit?

A full kit of parts, which includes the PCB and all the parts that are to be fitted, will be available. The UART is not part of the kit because it is not normally needed but can be obtained from me. A 'picking list' will be supplied on request and all parts are priced at the cost of the parts and input postage to me (I can be reached at the e-mail address at the top of the column).

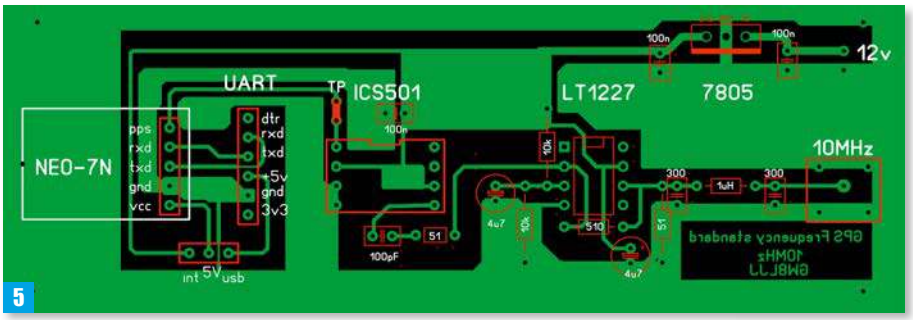

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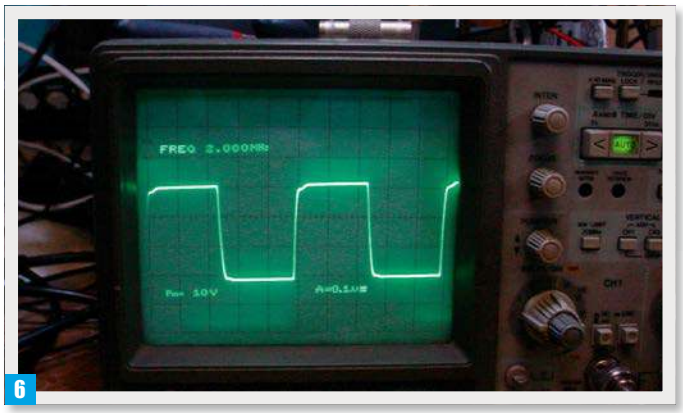
Fig. 5: PCB layout. Fig. 6: 2MHz base signal. Fig. 7: 10MHz output from multiplier.



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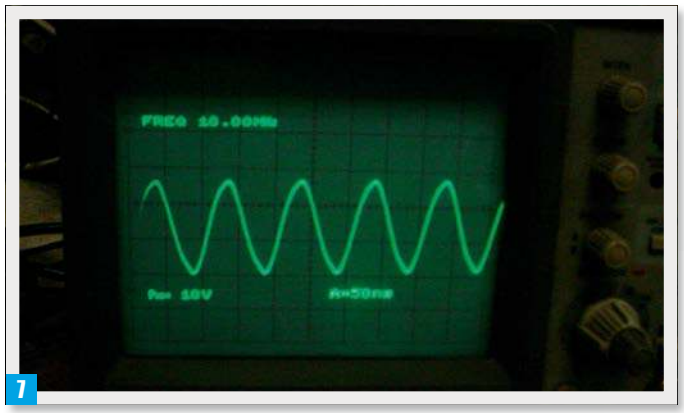

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An antenna will be needed and the connector may need to be changed to an SMA plug. For the GPS module, Google 'U-blox 7 GNSS modules' for sourcing and datasheet. For the GPS software, Google 'U-blox u-center'. The UART is the SILAB CP2102. Finally, my thanks to Ray G7BHQ for help with software and proof reading.

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